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Status and outlook for Thailand's low carbon electricity development

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A B S T R A C T

Thailand is facing an urgency to enhance its energy security and capacity to cope with global warming impacts, as demands on fossil fuel consumption keep rising. This paper reviewed the latest situation on renewable powers and developmental strategies toward low carbon electricity generation in Thailand. Government recently has spent tremendous financial and legislative supports to promote the uses of indigenous renewable energy resources and fuel diversification while contributing in reduction of global greenhouse gas. Major policy challenge is on which types of renewable energy should be more pronounced to ensure sustainable future of the country. Regions in Thailand present different potentials for renewable supply on biomass, municipal wastes, hydropower, and wind. To maximize renewable energy development in each area, location is matter. Currently, energy-derived biomass is widely utilized within the country, however if droughts happen more often and severe, it will not only affect food security but also energy security. Life cycle of biomass energy production may cause other social issues on land and chemical uses. Meanwhile, deployment of wind and solar energy has been slow and needs to speed up to the large extent in comparison with energy proportion from biomass. Nuclear power has already been included in the Thai power development plan 2010 (PDP-2010). However, public acceptance is a major issue. Setting up strategic renewable energy zone to support power producer according to pre-determined potential location may assist development direction. Furthermore, government has to strongly subsidize research and development to lower technology cost and promote private investment on renewable energy industry. In the future, revision of electricity price is needed to allow fair competition between non-renewable and renewable energy once subsidy programs are ended. Environmental tax according to fuel types could help government progressing toward low carbon electricity. Stimulating renewable energy development and utilization at local community is a key for Thai sufficiency economy.

Contents

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1. Introduction

Power generation is the main source of carbon dioxide emissions and accounts for four in every ten tons of carbon dioxide dispatched to the Earth's atmosphere. How countries generate electricity, how much they generate, and how much carbon dioxide gets emitted with each unit of energy produced is critical in shaping the prospect for stringent climate change mitigation. International Energy Agency expressed the use of energy by far the largest source of GHGs emissions from human activities, dominated by the direct combustion of fuels [1]. Energy accounts for over 80 percent of the anthropogenic greenhouse gases in Annex I countries, with emissions resulting from the production, transformation, handling and consumption of all kinds of energy commodities. With climate change threats, the levels of GHG need to be stabilized and eventually reduced. Clearly, our consumption of fossil fuels must decrease, partly due to a limited and uncertain future supply and partly because of undesirable effects on the environment [2]. Essentially, a sustainable supply of energy for societal needs must be secured in long-term for our future generations. With well-founded scientific supports and international agreement, renewable energy sources must be urgently developed and widely adopted to meet environmental and climate related targets and to reduce our dependence on oil and secure future energy supplies.

As developing country that heavily depending on imported fossil fuels for power generation, Thailand already experienced adverse impacts of energy crisis that could become major barriers for the country's future development. The country improves its power development plan for the next decades to enhance higher proportion of renewable energy generation. The critical questions are how realistic of the plan' s targets compared to existing physical supplies and technical potentials, which technology should be more pronounced, and how fast the plan's impacts can be acknowledged [3]. During 1993–2008, carbon dioxide emissions from electricity generation in Thailand have increased by 16.5 percent and this large amount is the result of demand growth in electricity production (27.8 percent between 1993 and 2008). Department of Alternative Energy Development and Efficiency (DEDE) reported the forecasted amount of GHGs emission from Thailand would reach 559 $MtCO_2$ over period 2005–2020. Fig. 1 shows historical emission trend from electricity generation in Thailand during 1986-2008. Average growth of total GHGs emission is estimated to be 3.2 percent per year while estimated emission from energy sector is 4.7 percent per year [4]. Ministry of Energy (MOE) reported the CO_2 emission per capita of Thailand increased from 1.85 to 3.06 during 1993 to 2008 and electricity consumption per population raised from 965 to 2129 kWh per capita during 1993 to 2008, respectively [5]. The study of the Electricity Generating Authority of Thailand (EGAT) estimated every one kilowatt-hour of electricity produced in Thailand emits CO_2 approximately 0.5 kilogram. To strengthen national energy security and reducing GHG emission from energy sector, Thailand could effectively promote renewable energy generation from its main agricultural products and residues.

Agriculture is a major business for Thailand. High potentials for all types of renewable energies based on agricultural products exist in the country and can help strengthen the national energy security. Thai Government currently has launched ambitious programs to enhance investments in renewable energy e.g. wind, solar, biomass, and other clean renewable energy sources. In fact, to secure future energy supply and incorporate the government renewable energy efforts into actual utilization, it is not quite a straight thinking. There are some hurdles after implementation. One is that the commission of power plants and the transmission of power into grid may take between 5 and 7 years. Thailand's power purchase from a foreign source is limited. Power plant investments especially in renewable energy involve large number of stakeholders, therefore require all partners to understand and negotiate their trade-offs, benefits and impacts. Thus, the power development plan must be strategically designed. Inevitably, a reliable medium and long run load forecasts are prerequisites for a well-conceived power development plan.

This paper intends to review a recent situation of power generation and renewable energy development strategies in Thailand including the nature of business operation, the governmental regulations, power development plan and its implementation/performance. Mainly, the analytical evaluation of the current technological capacity and country pathway toward low carbon electricity generation is a highlight of this review. The existing physical potentials and technological feasibility are examined and compared with the country's development targets. Factors supporting and hindering the achievement of future low carbon electricity in Thailand are elucidated. The paper aims to present useful information and lesson learned for other countries that may face similar situations.

2. General situation in Thailand's electricity sector

Electricity is one of the necessities in the ordinary business of life, and a major driving force for world economic growth and development, Thailand without exception. With un-storable nature of electricity, the supply of electricity must always be available to satisfy the growing demand. Since 1968, Thailand electricity supply services have all been taken over by the state government and operated under state enterprises under a law empowering its monopoly. The state utilities accumulated assets and built up their manpower to expand and operate the power

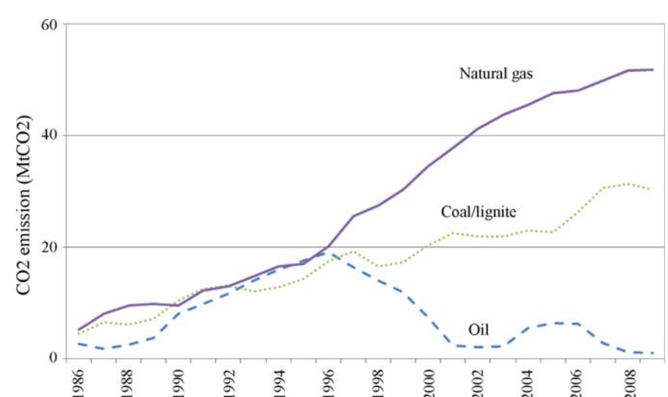


Fig. 1. Carbon dioxide emissions from electricity generation in Thailand.Source: Ministry of Energy [40].

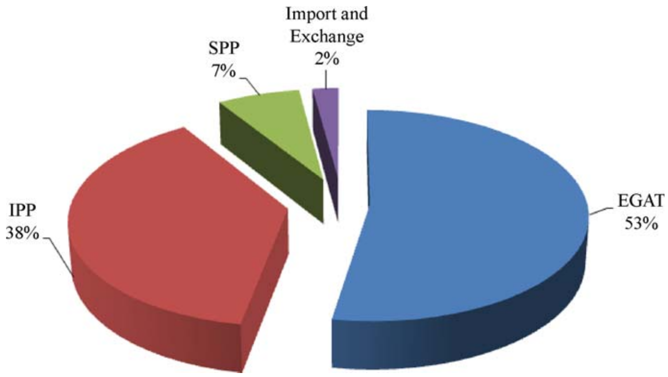


Fig. 2. Share of electricity supply in 2009.Source: Ministry of Energy [40].

system to serve the whole country [6]. Thai power system has a single buyer structure that the Electricity Generating Authority of Thailand (EGAT) currently provides about 53 percent of the country's electricity supply. EGAT plays the main role not only in generating country's electricity but also in operating all high voltage transmission lines and monopolizing the buying power of the country's electricity [7]. EGAT sells bulk power to two distribution utilities; (a) the Metropolitan Electricity Authority (MEA) responsible for the sale of electricity within Bangkok and surrounding areas; and (b) the Provincial Electricity Authority (PEA) responsible for electricity sale in the remaining parts of the country. Additionally, private power producers sell electricity to the electric utilities under power purchase agreements or to users located nearby. Since early 1990s when high growth in power demands existed, the government developed several initiatives to privatize state electric utilities and engage independent power producers (IPPs) with long-term power purchase agreements (PPAs) for supply of electrical power into the grid system (Fig. 2).

During the past 15 years (1993–2009), the electricity consumption in Thailand increased from 56,279 to 135,420 GWh and peak demand of electricity increased from 9730 to 23,051 MW. As of January 2010, peak demand of electric power system was recorded at 12,569 MW and peak consumption of electricity was 148,518 GWh with 78.5 percent of load factor. Energy Policy and Planning Office (EPPO) [8] reported the total electricity consumption in 2009 can be categorized by economic sector as residential 30,258 GWh (22.5%), commercial 32,634 GWh (24.2%), industrial 59,402 GWh (44.1%), agricultural 316 GWh (0.2%), direct customer 2894 GWh (2.1%), and other 9289 GWh (6.9%), respectively (Fig. 3). The power sector in Thailand like in many other developing countries is heavily dependent on fossil fuels (Fig. 4). The electricity installed capacity can be categorized based on

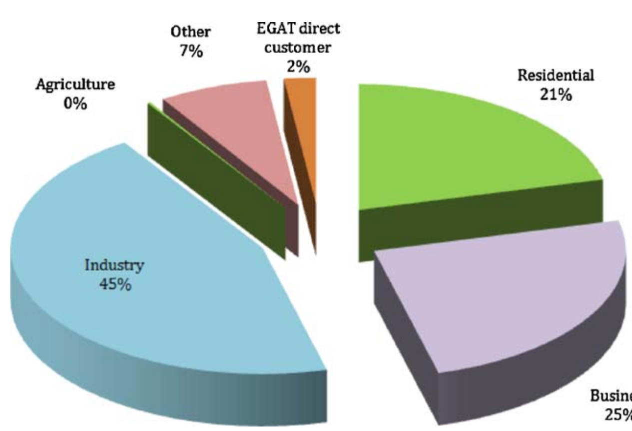


Fig. 3. Electricity consumption in 2009.Source: Ministry of Energy [40].

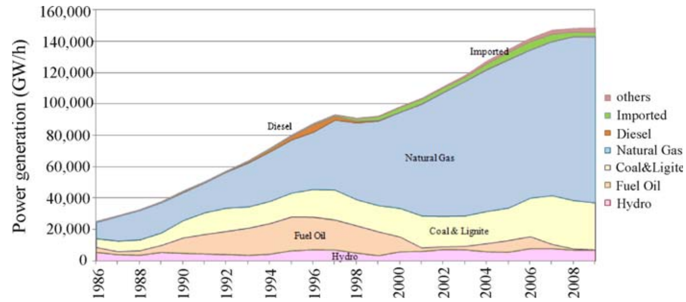


Fig. 4. Capacity and fuel share of Thailand's electricity generation.Source: Ministry of Energy [40].

power plant types as hydropower of 3764 MW (13.6%), thermal power plants of 9667 MW (34.8%), combined cycle power plants of 12,806 MW (46.0%), gas turbine and diesel power plants of 972 MW (3.5%), and renewable power plants of 279 MW (1.0%) including the Thailand–Malaysia interconnection grid at 300 MW (1.1%). Much of this capacity based on thermal and combined cycle generation where natural gas alone contributes to over 73.9 percent of total electricity generation, followed by lignite and coal at about 17.4 percent, hydropower at 3.6 percent and fuel oil at 1.4 percent, respectively [9,10]. Fig. 5 illustrated the distribution of conventional and non-conventional power plant in Thailand.

3. Expansion policy and power plant technologies

Thailand is highly dependent on natural gas for electricity generation and its utilization accounts for about 74 percent of the total fuel used to produce electricity. About 75 percent of the gas used for all purposes, including for industry comes from the Gulf of Thailand and the rest from Myanmar and could be vulnerability for power generation. The country may face a risk of natural gas shortages as industrial activity rises in response to the improving economy, resulting in higher power demand; however, high dependence on single fuel type in power generation raises concerns about security of electricity supply that could affect competitiveness of Thai industries at the global level. The country has faced shortages of natural gas recently that could become a serious threat in the near future [9,11–14].

To power future energy supply, Thailand issued the 20 years Power Development Plan covered a period 2010–2030 (PDP-2010), to enhance reliability of power supply, fuel diversification, power purchase from neighboring countries, power demand forecast and others. The PDP-2010 was approved by the National Energy Policy Council (NEPC) and endorsed by the cabinet in April 2010. The PDP-2010 aims to reduce the country's dependence on natural gas from 68.2 percent to 55.6 percent in 2030 while increasing the use of renewable fuel from 14.7 to 19.0 percent and nuclear power to 5.3 percent. At the same time, the use of lignite will be cut from 9.1 percent to only 6.4 percent. Under PDP-2010, the total install capacity is 36,335 MW and the total capacity of retirement of old power plants is 19,974 MW which is divided into 3046 MW of EGAT thermal power plants; 4776 MW of EGAT combined cycle power plants; 2927 MW of Thermal IPP power plants and 9225 MW of IPP combine cycle power plants [10].

The Energy Industry Act, B.E. 2550 (2007) came into force on December 11, 2007 and established a new regulatory regime for electricity and natural gas business. One of the main objectives of this act includes promotion of the use of renewable energy. The cabinet approved a 15-Year of Alternatives Energy Development Plan (AEDP) on January 28, 2009. The announced goal is to speed up the utilization of renewable energy to constitute up to 20 percents of total energy consumption by 2022. Policies that came out from the plan will promote energy security of the kingdom

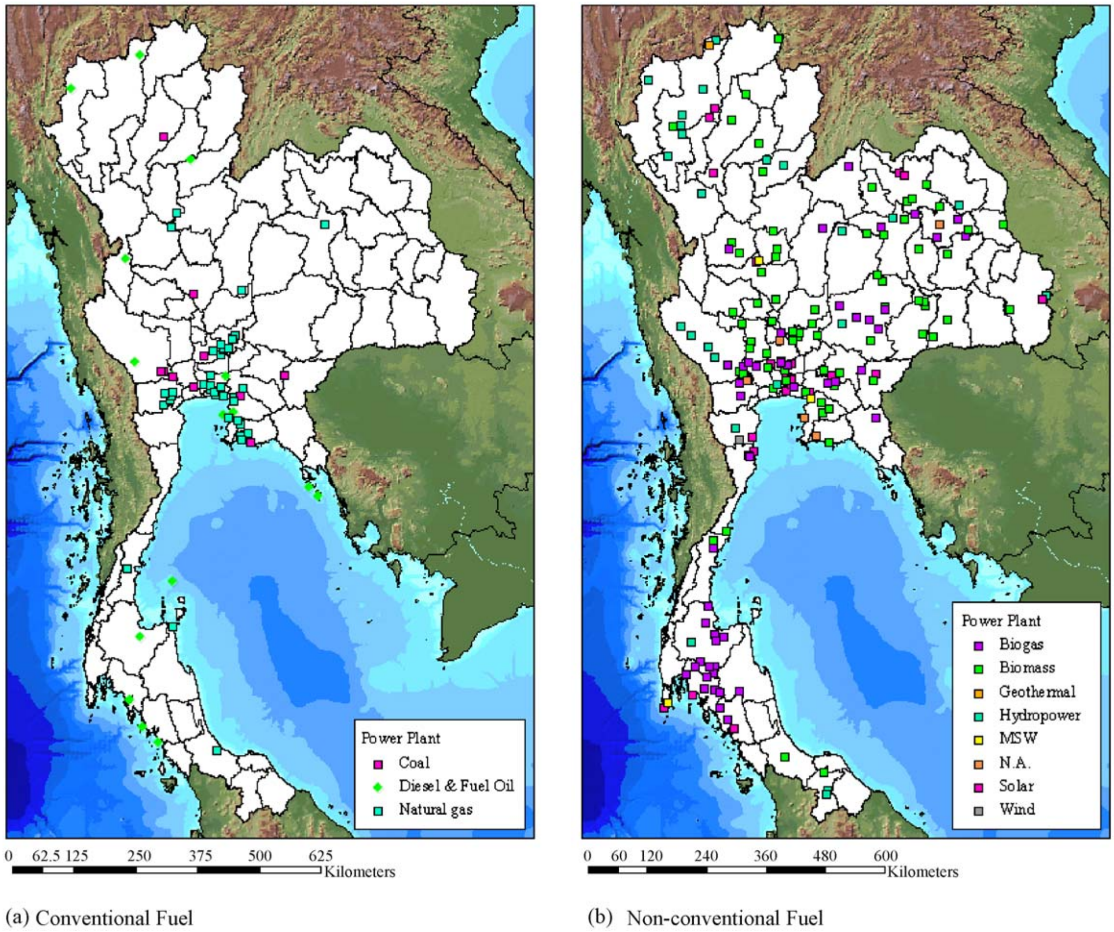


Fig. 5. Distribution of power plant in Thailand: (a) conventional fuel and (b) non-conventional fuel.Source: OERC [18] and EPPO [8].

by reducing energy imports and increasing domestic energy resources, building competitive energy market for sustainable economic growth, and help reducing the emission of greenhouse gases in the long-run [15]. For increase sharing of renewable energy mixed to 20 percent of the final energy demand in 2022, the AEDP is divided in to three phases: the short-term from 2008 to 2011, the mid-term from 2012 to 2016, and the long-term from 2017 to 2022.

The ADEP detailed target for electricity generation from renewable sources is summarized in Table 1. The short-term focuses on extending renewable energy proportion to 15.6 percent of the total energy consumption by promoting of proven renewable technologies and high-potential renewable resources such as biofuels and thermal energy generation from biomass and biogas with full financial supports. The mid-term expansion goal is to boot up renewable consumption to 19.1 percent of the total energy consumption. The mid-term strategy is concentrated on the efforts to promote the renewable technology industry, to support the new renewable technology prototype development to make it economically sound, to encourage cutting-edge technologies in the biofuels production and the green city model development, and to strengthen the local energy production. The long-term development goal is to develop the renewable energy at 20.3 percent of the total energy consumption. The long-term development plan focuses on adoption of economically viable cutting-edge renewable technology including the further implementation of the green city and decentralization of the technology to local community, as well as on promoting Thailand to become the ASEAN biofuels and renewable energy technology hub.

Table 1
Target for electricity generation from renewable energy during 2008–2022.

Unit (MW)	Actual 2009	Target		
		2008–2011	2012–2016	2017–2022
Solar	32	55	95	500
Wind	1	115	375	800
Mini/micro-hydropower	56	165	281	324
Biomass	1610	2800	3220	3700
Municipal solid waste	46	78	130	160
Biogas	5	60	90	120
Total	1750	3273	4191	5605

Source: Ministry of Energy [15] and EGAT [10].

The National Energy Committee (NEC) approved tariff adders for certain categories of alternative energy on March 9, 2009. This allows government to encourage the renewable energy investment by awarding "adder tariff" or special purchasing rate higher than the price of power generated from mainstream fuels to private power producers depending on the types of renewable fuel used (Table 2). The efforts have been made to diversify the economy away from the use of oil and natural gas for power generation by, among others, increasing the use of indigenous renewable energy resources and implementing fuel energy-efficient technologies for power generation to enhance the security of national power supply as well as to reduce local and global environmental impacts.

4. Status of renewable energy utilization

Since energy demand is projected to keep increasing, renewable energy and alternative energy are considered potential options to

Table 2
Adder to the normal tariff for increase incentives for renewable energy expansion.

Fuel type	Adder		Target in 2009–2021 (MW)
	Baht/kWh	US cents/kWh	
Biomass			3700
<1 MW	0.50	1.43	
>1 MW	0.30	0.86	
Biogas			120
<1 MW	0.50	1.43	
>1 MW	0.30	0.86	
Waste			160
Fertilization/landfill	2.50	7.14	
Thermal process	3.50	10	
Wind			800
<50 kW	4.50	12.86	
>50 kW	3.50	10	
Hydropower			324
50 kW to <200 kW	0.80	2.29	
<50 kW	1.50	4.29	
Solar	8.00	22.86	500
Total capacity			5604

Source: Ministry of Energy [15].

accommodate the increasing energy demand. Renewable energy utilization will help reducing not only the country's dependency on imported energy but also risks of volatility of imported fuel prices. At present, the development of renewable/alternative energy has become a country focus by promoting wider utilization of renewable energy to replace conventional energy consumption and motivating people to use energy efficiently and economically. This section gives an overview of alternative energy utilization in Thailand in several aspects including technological and supplying potential of biomass, biogas, municipal solid waste, hydropower, wind, solar, geothermal and nuclear energy to check on how obtainable for Thailand to achieve the latest AEDP target leading toward a low carbon electricity in 2022.

4.1. Biomass

Thailand is an agricultural country with huge agricultural stocks, such as rice, sugarcane, rubber sheets, palm oil, and cassava. The processing of these agricultural products generated large amounts of residues, which some parts are used as fuel in several industries. The amount of agricultural residues is about 61 million ton a year, of which 41 million tons, which is equivalent to about 426 PJ of energy, was left unused. Currently, biomass is the primary source about 4 percent of the country low carbon electricity. MOE indicated three main biomass sources in Thailand are from agricultural residues, forest industry and residential sector [16]. The employable biomass energy in Thailand mainly includes crop residues, firewood, manure, domestic garbage, industrial organic waste residue, and wastewater. The most promising residues used as fuel sources in electricity generation and cogeneration are rice husk, bagasse, palm oil residue and rubber wood residue. The utilization of biomass applies in wide range of conversion technologies such as direct combustion, thermo-chemical conversion, biochemical conversion, direct liquefaction, physical/mechanical extraction, and electrochemical conversion. Based on commercial application so far, direct combustion and thermo-chemical conversion are the most applicable technologies for utilizing biomass for heat and power generation [17].

The potential from biomass supply is widely distributed throughout the country depending on seasons. Particularly, rice is main agricultural product. The rice statistics data in Thailand were roughly represented according to major harvest and second harvest. Major harvest would be from May/June until November/December and second harvest is from December/January until May/June. Table 3 summarized the potential of major crops for biomass development in Thailand.

The Office of the Energy Regulatory Commissioner (OERC) reported the installed capacity of biomass power generation in Thailand reached 1751 MW. Of this, the power capacity from 632 MW from rice husk, 106 MW from bagasse and 32 MW from wood residue [18]. EPPO [8] reported in March 2010, there are 76 biomass power plants in operation (637 MW), 30 plants in the negotiation period with PEA and MEA (234 MW), 40 plants in acceptable period but not yet singing PPA contract (290 MW) and 211 power plants in the construction period and waiting for Commercial Operation Date (COD) at 1586 MW [19]. Under the 15-years of AEDP, government set targets of biomass utilization in electricity generation in 2022 into three periods, short-term (2008–2011) at 2800 MW, mid-term (2012–2016) at 3220 MW, and long-term (2017–2022) at 3700 MW, respectively.

4.2. Biogas

Thailand is known as a food producing and supplying country. Food and agro industry generated significant amount of organic wastes, which are good ingredients for biogas production. The productions of biogas are mainly from anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, and energy crops. In Thailand, biogas resources are from industrial wastewater and livestock manure, which have potential of 7800 and 13,000 TJ per year, respectively. Central region produced highest BOD loading of 2233 ton/day, which was more than half of the total BOD loading. The amount of wastes can be used to produce 620 million m^3 of biogas, which is equivalent to about 13,000 TJ or 308 ktoe of energy, in anaerobic

Table 3
Evaluation of biomass potential in 2009.

No	Main crop	Yield (million ton)	Biomass	Estimated biomass (million ton)	Non use fraction	Potential biomass (million ton)	Estimated potential energy	
							TJ	ktoe
1	Rice	31.50	Rice husk	7.25	0.19	1.38	18,611.76	444.53
			Rice straw	15.55	0.29	4.48	55,193.31	1318.27
2	Sugarcane	73.50	Sugarcane leaves	12.49	0.55	6.87	106,384.76	2540.96
3	Casava	8.22	Casava trunks	0.74	0.41	0.30	4727.26	112.91
			Casava rhizome	1.64	0.66	1.08	5955.03	142.23
4	Corn	6.91	Corn cobs	1.66	0.70	1.16	11,160.29	266.56
			Corn trunk	5.66	0.61	3.40	33,397.17	797.68
5	Palm	8.16	Palm cluster	2.61	0.38	0.99	7185.02	171.61
6	Rubber	232,008.94 (rai)	Rubber slap	0.70	0.41	0.29	1874.89	44.78
			Roots	1.16	0.95	1.10	7240.42	172.93
7	Other wood		Woodchips	1.89	1.00	1.89	12,407.45	296.35
	Total			51.35	6.15	22.94	264,137.36	6308.81

Source: Office of Agricultural Economics, Ministry of Agriculture [41], Department of Livestock, Ministry of Agriculture [42].

digesters [20]. Although cattle residues show the highest energy potential of 41 percent of the total energy potential, the ongoing biogas promotion program is emphasized on manure utilization from pig farms. In the future, the government certainly has to put more focus to utilize resources from cows as well.

The OERC reported the installed capacity of biogas power in Thailand reached 146 MW. Of this, the power capacity from 74.96 MW from industrial wastewater and 97 MWh from pig manure [18]. EPPO [19] reported in March 2010, there are 41 biogas power plants in operation and sale power to grid at capacity of 43 MW, 15 plants in the negotiation period with PEA and MEA (41 MW), 31 plants in acceptable period but not yet signing PPA contract (44 MW) and 33 plants in the construction period and waiting for COD (72 MW). Under the 15-years of AEDP, government set targets of biogas utilization in electricity generation in 2022 in three periods, short-term (2008–2011) at 60 MW, mid-term (2012–2016) at 90 MW and long-term (2017–2022) at 120 MW, respectively.

4.3. Municipal solid waste

Management of municipal solid waste (MSW) has continued to be an important environmental challenge due to increase in production and consumption of goods. The threat of global climate change become a driving force and great opportunity to change MSW management practices to reduce greenhouse gas emissions in Thailand [21]. Huge amounts of waste are generated daily and its management is a considerable task to not only promote recycling and reuse, efficient waste collection and disposal system, but also increase financial capability and effective participation of government, public and private sectors. Thailand generates approximately 14.5 million tons of municipal solid waste (MSW) annually. Chiemchaisri et al. [22] clarify the physical composition of MSW varies according to consumer patterns, lifestyle, and economic status. The detailed composition of MSW in Thailand dominated by food waste (41–61%), followed by paper (4–25%) and plastic (3.6–28%). Within landfills, microorganisms that live in organic materials such as food wastes or paper cause these materials to decompose and produce landfill gas typically comprised of roughly 60 percent methane and 40 percent carbon dioxide. Total numbers of landfills in Thailand that actively operate are ninety while total incinerators are three. There are more than three hundred opened-disposal sites in the country. Despite large numbers of landfills, only a few of them properly operate and maintain (with methane gas collection) because no regulation mandates for methane collection.

The OERC reported the installed capacity of electricity from municipal solid waste in Thailand reached 13 MW [18]. EPPO reported in March 2010, there are 8 municipal solid waste power plants in operation and sale electricity to grid at 11 MW, 10 power plants in the negotiation period with PEA and MEA (305 MW), 15 plants in acceptable period but not yet signing PPA contract (68 MW) and 14 plants in the construction period and waiting for COD (96 MW). Under the 15-years of AEDP, government set target of biogas utilization in electricity generation in 2022 in three periods, short-term (2008–2011) at 78 MW, mid-term (2012–2016) at 130 MW and long-term (2017–2022) at 160 MW, respectively [19].

4.4. Hydropower

Water supply for the whole part of Thailand is plentiful, except in the northeastern part of the country during the dry season. Thai's culture has long been intimately related with water, but not in a seafaring way, instead mainly in a local transport and irrigation mindset. Based on geographical characteristics watershed of Thailand divided into 25 river basins, average of annual rainfall is about 1700 mm and total annual rainfall of all river basins is about 800,000 million m^3 of which 75 percent of the amount is lost through evaporation, evapotranspiration and the remaining is in streams, rivers, and reservoirs. Hydropower is the second major source of low-carbon electricity for Thailand. Hydropower produces only small amounts of CO_2 as a by-product from dam construction and operation, but in some cases may produce significant amounts of another greenhouse gas, methane. However, hydropower resources are difficult to exploit due to the environmental impact on the resource areas a power project would entail. Therefore, future development of hydropower resources will be limited to a few small-scale projects that are considered most economical and environmental friendly. As part of the rural electrification program, the small hydropower developments are promising plan. From survey of MOE presented Thailand has potential to development of small hydropower at existing irrigation project. According to the PDP-2010, EGAT planned to increase capacity by constructing small hydropower at total capacity of 49 MW within 2012 [15]. There are many existing irrigation dams and reservoirs of Royal Irrigation Department (RID) designed and constructed for irrigation and flood control. Six existing and under construction dams of RID were studied and proposed by EGAT to develop the small hydropower projects with the total installed capacity of 78.7 MW. High potential micro-hydro powers are clustered in the northern areas of the country [10,23].

EPPO [19] indicated hydropower existing potentials for development is at 15,155 MW [24]. By the end of December 2009, the OERC reported the installed capacity of hydropower in Thailand reached 3438 MW [18]. EPPO reported in March 2010, there are 7 hydropower projects in acceptable period waiting for COD at capacity of 6.3 MW. Under the 15-years of AEDP, government set target of hydroelectric utilization in electricity generation in 2022 in three periods, short-term (2008–2011) at 165 MW, mid-term (2012–2016) at 281 MW and long-term (2017–2022) at 324 MW, respectively.

4.5. Wind

Wind energy technology currently has conquered many startup problems and has attained in a new, more mature phase. It is one of the promising alternatives to implement for low-carbon electricity generation. The average wind speed in Thailand is moderate to rather low, usually lower than 4 meters per second; therefore, wind energy is currently used almost exclusively for propelling rooftop ventilators and water-pumping turbines. Throughout Thailand's long coastline, there is a rich resource of wind energy with great development potential. Currently, a further detailed study is being carried out in areas where the wind potential is high, mainly along the southern coastlines of Thailand, to obtain more data with a view determining the feasibility to develop projects for wind power generation [24,25]. The study of Prabamroong et al. [26] estimated total feasible areas for wind farm installations with respect to total area in each region of the country is found to be 95 percent for Central region, 88 percent for Eastern region, 94 percent for Northern region, 79 percent for Northeastern region, and 91 percent for Southern region. This study suggested that most of areas in Thailand have high potential for installing wind farms.

By the end of December 2009, the OERC reported the installed capacity of wind power in Thailand are in very small amount about 0.38 MW [18]. As of March 2010, EPPO reported there are 3 wind power projects in operation, 19 in the negotiation period with PEA and MEA (762 MW), 16 projects in acceptable period but not yet signing PPA contract (560 MW) and 6 power plants in the construction period and waiting for COD (26 MW) [19]. Under

the 15-years of AEDP, government estimated potential of wind energy utilization with 1600 MW capacity and set target of wind energy utilization in 2022, short-term (2008–2011) at 115 MW, mid-term (2012–2016) at 375 MW and long-term (2017–2022) at 800 MW, respectively. Noticeably, the government proposed to increase renewable energy from wind power to 800 times more from the current capacity in 2022. This will require significant amount of investment, which the government needs to carefully develop an appropriate driving policy to succeed this ambitious goal in 12 years.

4.6. Solar

Almost every area in Thailand exposes to high sunlight intensity since locating near the equator. Therefore, high potential for solar utilization exists. Government promoted solar cells or photovoltaic (PV) cells for power generation with a demonstration project for utilization of solar energy and integrated systems of PV/hydropower and PV/wind energy [27]. Since 1976, the Ministry of Public Health and the Medical Volunteers Foundation used solar electricity for communication equipment in rural health station in isolated area that far from grid system. Several government agencies under the MOE have been undertaking studies and development of PV technology. For example, DEDE has studied and explored the potential of solar energy utilization by establishment of solar cell battery-charging station in various rural villages and Border Patrol Police Schools located outside the grid system [28].

By the end of December 2009, the OERC reported the installed capacity of solar power in Thailand are 7.8 MW [18]. EPPO [19] reported in the end of March 2010, there are 51 solar power projects in operation with capacity of 7.7 MW, 121 projects in the negotiation period with PEA and MEA (996 MW), 61 power plants in acceptable period but not yet signing PPA contract (218 MW) and 341 plants in the construction period and waiting for COD (3265 MW). Under the 15-years of AEDP, government set target of solar energy utilization in 2022, short-term (2008–2011) at 55 MW, mid-term (2012–2016) at 95 MW and long-term (2017–2022) at 500 MW, respectively. The proportion of solar energy is about 10 percent compared to total renewable energy target, which seems to be relatively low, despite the great potential of solar intensity throughout the whole country. High investment cost per unit of electricity might be a major barrier, which suggests the government should find the way to develop R&D and support domestic solar industry.

4.7. Geothermal

Geothermal energy is natural energy from the internal heat of the earth; the temperature varies with respect to the distance from the earth surface (geothermal gradient) – the deeper from the earth surface, the higher temperature. At the depth of about 25–30 km, the average temperature will be around 250–1000 °C. There are approximately 64 geothermal resources in Thailand, but major ones are in the northern part of the country, especially the geyser field at Fang District in Chiang Mai Province. Currently, EGAT is operating a 300-kW binary cycle geothermal power plant at Fang District, generating electricity at about 1.2 million kWh per year, which helps reduce oil and coal consumption for power generation. In addition, other benefits derived from the waste heat of hot water used in the power plant. The temperature of hot water, after being used in the power plant, will decrease from 130 °C to 77 °C, which can be used for drying agricultural products and feeding the cooling system for EGAT's site-office space. Some other non-energy uses of hot water from geothermal sources are for physical therapy and tourism [24]. Due to limited geothermal resources in the country, Thailand has small potential to produce more renewable energy from this area.

4.8. Nuclear energy

Thai Government is considering installing nuclear power to cope with future energy demand increases. Growing electricity demand, fluctuation of fossil fuel prices and climate change pressure bring all in a favor of nuclear power. The use of nuclear power will also help achieving emission reduction goal for climate change in the future. Therefore, Under PDP-2010, five thousand megawatt of nuclear power plant (5000 MW) are expected to start operations during 2020–2030 and the first nuclear power plant will operate in 2020 [10].

Government believes that modern nuclear plants are safe and have high quality-control standards. Within 2012, the cabinet will make the final approval on the construction of the first nuclear power plant based on the results of the feasibility study on infrastructure information, utility and public acceptance. However, human factor is often weak point in the use of advanced nuclear technologies; education is very important, training also a key issue to develop specific behavior that can make the different between industrial culture and safety culture, which is critically required by nuclear operation. Now, the systematic process of nuclear development program will require both a strong political will and people's acceptance to be open and transparent in order to create public trust by providing essential and precise information to the public along with the benefits to the country.

5. Barriers for renewable energy development

Despite high potentials to generate electricity from renewable sources in Thailand, several barriers still prolong the speed of development and wide adoption of renewable energy. Systematic support and promotional policy guidelines of the government is currently necessary to help alleviate the investment costs for renewable power generation development so as to eventually enhance its commercial and competitiveness. Appropriate financial support is key mechanism to further promote the development of power generation technologies from each type of domestic renewable energy sources. Based on our investigation, major factors hinder progresses of renewable energy implementation in Thailand are following:

5.1. Fuel supply

The limitation of raw material supply has recently become the prominent barrier for expansion of renewable energy utilization especially for biomass. Due to seasonal and spatial variation of biomass supply, it restricts the power plants unable to have a continuous operation or operate to the full capacity. This greatly affects the cost-effectiveness of the business. Moreover, the quantity and quality of renewable resources has become the prominent barrier. Most of biomass resources can only produced during harvesting season; for example, period of sugar harvesting is limited (5 months from December to April). Thus, electricity from the sugar factory is mostly seasonal [29,30]. Moreover, the intensive cultivation of biomass may stress water resources, deplete soil nutrients, and displace open space by withdrawing land from other natural uses. Large-scale production of biomass for energy purposes could compete with use of land, water, and energy for production of foods or woods and grasses for construction of shelters.

Logistics and transportation of renewable resources especially biomass fuel are the another barrier of renewable energy utilization. Most of renewable energy is bulky and distributed

over vast areas, which could cause high transportation expenses. Biomass resources should be utilized by nearby facility. If biomass has to be transported by farm equipment much over 100 km to a processing point or use facility, a substantial fraction of the energy content of biomass itself is consumed in the transportation process [31]. According to government policy on fuel diversification to renewable energy, the declaration of sufficient fuel supply to prevent fuel shortage is the main criteria used for selecting the small projects to receive feed-in tariff or ''adder'' from EGAT or PEA.

5.2. Technical barrier

The absence of efficient renewable energy generation technologies and supports of skilled manpower and spare parts is one of the prime technical barriers. For example, domestic wind power technology has not well developed in the country, so the advanced and large wind power sector has to rely on imported technology. Given the available wind resources and climatic conditions, it is difficult to further develop wind power sector in Thailand by using imported technologies. The technology has to be tailored to adopt in the hot and humid climate and low wind speeds prevalent in Thailand. In long-term, this can pose substantial barrier if we continue importing foreign technology for wind energy development in Thailand. Another example in solid waste utilization, characteristic of solid wastes in Thailand has high moisture contents therefore have low calorific value which is unsuitable to use in power generator and required additional processes to improve fuel quality e.g. installation of waste separation unit or manual waste separation [32]. Increase efficiency of waste separation can help increasing the yield of biogas generation but it also requires public education on waste management.

For technological R&D, Thailand needs to support researchers to carry out their research to extend our country potential, and create in-house technology to promote industrial start-up. Many believe that accelerating the pace of technology improvement and deployment could significantly reduce the cost of achieving this goal. The critical role of new technologies is underscored by the fact that most anthropogenic greenhouse gases emitted over the next century will come from equipment and infrastructure built in the future. As a result, new technologies and energy sources have the potential to transform the nation's energy system while meeting climate change as well as energy security and other important goals [33,34].

5.3. Financial barrier

A key role for government is to focus on policy design and legislation to attract private sector investment. As renewable energy technology becomes more commercially mature, government will become less significant as providers of the direct capital support needed to make up the cost difference relative to conventional generation. Mallon [35] express the importance of cost internalization (environmental and social damage cost) made cost of renewable comparable with thermal (nuclear and fossil) electricity generation. Siegel et al. [36] express investment of renewable energy companies not only generates revenues by providing clean, green power for consumers, but they can also generate additional revenues by simply offering an ''offset'' to companies that emit less greenhouse gas emissions (GHG). It is clearly beyond the budgets of most government to directly inject money into renewable in order to fast track a competitive industry. A handful of demonstration projects might be useful, good examples of financial incentive provided by the Ministry of Energy is ''ESCO Venture Capital Funds'' for providing equity for small renewable energy and energy efficiency projects undertaken by small entrepreneurs with limited capital. The fund should also be provided financial assistance for equipment leasing, credit guarantee facility, technical assistance and carbon market [7].

It should be noted that without subsidies, biomass power projects are unable to compete with fossil fuel power plants due to the difference in scale on which conventional plants and renewable energy plants operate [37]. Government set price at which they can sell their renewable power to the grid, thus effectively providing essentially a guaranteed return on the renewable energy investment and making it easier for renewable energy projects to obtain banking approval for the capital costs of the project. For example, waste incineration is not likely to be cost-effective at this time in Thailand. Incineration of municipal solid waste is a costly and operationally complex, as compared to landfills. Government subsidies are only possible sources of financing, however this issue is not a widely discussion upon by the public, politicians, and international financial institutions. Feed-in tariffs in practice have definitely provided a hugh boost for renewable energy projects.

Another barrier or driven constrains of biomass utilization are still high in price. Fluctuation of fossil fuel price also affects the competitiveness and utilization of renewable energy. Moreira expressed most of modern biomass utilization are being driven by energy security motivation [38]. Fossil fuel price has been increasing in the last 3 years due to various reasons, when fuel price are high, some industries change their main fuels from fossil fuel to use rice husk for lowering price. Average price of rice husk has increased from 767–799 THB/ton in 2006 to 864–1042 THB/ton in 2009. However, when the fossil price was dropped, demands for biofuels also decreased.

Tester et al. [31] indicated that if fossil fuel prices rise to include cost of carbon management, consumers may also modify their consumption patterns. Through a system known as carbon trading, a market – based mechanism that helps mitigate the increase of carbon dioxide in the atmosphere, renewable energy companies (as well as other entities that provide offsets, such as forestry management companies, for instance) can sell carbon credits to companies that emit carbon dioxide into the atmosphere and want to balance out their emissions. The government should refocus its energy development strategy and consider more on how to deliver the actual price of energy to the citizens, instead of lowering the price to favor industrial development without carefully considering environmental externality and social costs. The challenge is how to internalize all externality (e.g. environmental damages cost) caused by using fossil fuels, and set up a financial structure i.e. tax system to bring the right energy price to consumers. This will help promoting the fair competition between renewable energy and traditional fuels and bring the country to a sustainable future.

5.4. Institutional and legislative constrains

Today, even environmental friendly energy projects are also facing public protest. Hydropower projects can be particularly controversial because they can displace communities as large areas of land are flooded and prevent communities from having access to the water for current and future needs. Communities can be impacted greatly by having their water regime changed. Some hydro projects face several oppositions from groups that are not just local communities. No one wants this type of project to be located nearby his or her neighborhood. Though, renewable-energy projects would reduce pollution and combat climate change but on the other hands, the trade-off is that many people would have to see wind turbines, solar panels and other energy infrastructure near their homes in order to diminish the need for coal mines and other fossil-fuel facilities. Ball [39] express the

increment of renewable energy development issues on public concern such as environmental, energy securities and social impact was the key parameters for policy-maker or project developer to concern.

In Thailand, the laws require the project that may potentially cause environmental damage and health impact to conduct an environmental impact assessment and require public participation. For instance, the hydropower development project must concern on the ecological environment warrants close scrutiny and should be evaluated in a systematic manner before and during construction and operation of hydropower station. In Thailand, most of the areas that have high potential for renewable energy development e.g. wind, small hydropower and geothermal are belonging to government and inaccessible by the project investor. For example, under Section 46 of the Enhancement and Conservation of National Environmental Quality Act B.E. 1992 required an environmental impact assessment (EIA) report before submitting for license. Therefore, government needs to set up a special task force to examine potential areas for renewable energy development, and set up a fast track of permit procedure that help fasten the development. Moreover, government should strengthen environmental regulation and enforcement especially emission controls from very small private power producer (VSPPs) because currently there are no rules and regulation to control emission from power plant that has capacity below 10 MW.

6. Conclusion

Thailand faces the energy and environmental challenges as being both a contributor and victim of the effects of climate change. Renewable energy was identified as having great potentials, due mainly to ample physical supply of the industrial by-product such as rice husk, wood chips, bagasse, and other available biomass on fields. Based on potential installment of energy technology (in Table 1), in 2022, the major proportion of renewable energy will mainly derive from biomass 33.9 percents of total energy. To meet a target of 3700 MW biomass electricity generation capacity in 2022, Thailand need to increase about 129.8 percent from current capacity 1610 MW in 2009. The expected goal under AEDP is not too hard to achieve, but government must help increase efficiency of technology and methodology of biomass utilization, and explore other energy-derived biomass that should be more utilized.

The climate change is a direct threat to energy security, particularly to existing energy infrastructure. Examples of disruptions to energy supplies that could cause disruptions to power supply include droughts reducing hydropower availability and withering field crop and other food supplies. The effects of climate change may affect the trade-off between food supplies in term of food plantation area and purposed uses for biomass energy supplies. According to target of wind energy development under AEDP, the government estimated that our future would very much depend on wind energy (800 MW in 2022). However, development of wind energy utilization must be as fast as possible, comparing with biomass. For solar energy utilization, it is still uncertain about technological breakthrough to drive down the economic cost for this type of technology. This is a major challenge that government has to solve in order to promote widely implementation of the solar energy.

The government released many tools for motivate utilization of electricity generation from renewable energy in many different ways e.g. BOI investment scheme in renewable energy by giving fiscal incentives and tax exemption in hardware and equipments using in construction of renewable power plants, special soft loans via ESCO funds. Before implement financial incentives for renewable development, the government may need to assess actual renewable potential and should revise the potential of renewable energy development in order to set up "precise" and "effective" target before implementation. In addition, government should promote the zoning policy for renewable energy because of each part of country containing different types of supplying potential on biomass, hydropower, and wind. The location is important, however, some technology might not depend on location in term of solar energy.

Thailand has plenty of resources to generate electricity from the sun and wind, however, the challenging action for government is whether it should wait for technology to maturely develop and later adopt the cost-effective technology or government right now should strongly subsidy research to develop low cost solar cell by encouraging the co-operation of research and development. Moreover, government may urgently need to set up a policy to promote the decentralized solar system to household to reduce energy demand from the whole system and increase energy efficiency as in Europe. Promotion of decentralized energy production in household sector is important and collectively could create a big impact, including technology transfer to the public to become energy self-sufficient at local level.

In summary, Thailand has set a very ambitious intention for developing low carbon electricity sector. With high potentials of various renewable resources existed in the country, Thailand could potentially achieve it, but eventually how soon. With the government strong will in providing financial & regulatory incentives for business investment, R&D and public involvement to be part of the development, is really the key to build a strong foundation to secure the country's economy and environment.

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